Research on E-Learning in the Workplace 2000-2012:

A Bibliometric Analysis of the Literature

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Abstract

Research on e-learning in the workplace has proliferateded over the past decade. Various topics on e-learning in workplace settings have emerged, showing the complex, dynamic and multi-disciplinary nature of the field. In this context, there is a need for an extensive, thematic overview of related studies for a better understanding of this broad domain. Using co-word analysis and text analysis methods, this study presents a bibliometric analysis of 324 articles on workplace e-learning published in academic journals and conference proceedings from 2000 to 2012. The results identify six research themes in the field, which are further categorized into four dimensions: e-learning for continuing education and professional development, e-learning in the healthcare sector (as one of the most prolific e-learning initiatives), use of social media for e-learning, and the integration of knowledge management with e-learning. By incorporating the analysis results with relevant reviews, this study offers a comprehensive picture and a holistic view of the workplace e-learning domain, and suggests directions for further work.

Keywords: workplace learning, e-learning, bibliometric analysis, co-word analysis,

text analysis

1. Introduction

As a result of globalization and economic dynamics in recent decades, organizations are obliged to search for new ways to strengthen their competitive advantages. In this situation, improving workplace learning and human performance is crucial for sustainable development. Workplace learning is often depicted as informal learning that takes place without explicit teaching (Tynjälä, 2013). It refers to the continuous process of improving employee competence and performance through training, socialization, and development within an organizational context (Ford, Kozlowski, Kraiger, Salas, & Teachout, 1997). More recently, technology development and challenges in information-intensive and technology-oriented working life have led to new ways of learning and training through the adoption of e-learning or information and communication technologies. E-learning refers to the use of computer and network technologies, primarily over or through the Internet, to deliver information and instruction to individuals (Welsh, Wanberg, Brown, & Simmering, 2003). It encompasses a wide set of applications and processes such as computer-assisted learning, web-based training, virtual classrooms, and digital collaboration (ASTD, 2010). By virtue of its benefits in just-in-time delivery and cost efficiency, e-learning accounts for a significant proportion of corporate investment in training (Deeney, 2003).

Accordingly, the academic and professional literature on e-learning in the workplace has increased considerably in the past decade. A variety of topics and issues have been explored and discussed in various studies. E-learning has been investigated as "instructional medium" (Salas, Kosarzycki, Burke, Fiore, & Stone, 2002), "instructional strategy" (Klein, Noe, & Wang, 2006), "training method" (Burgess & Russell, 2003), "training technique," or "learning environment" (DeRouin, Fritzsche, & Salas, 2005a). Some studies have reported the confusion with regard to the typology of e-learning in an organizational environment (Burgess & Russell, 2003). The vagueness in terminology, spanning technology, pedagogy and organization, reflects the complex, dynamic knowledge and the uncritical views and approaches in the domain (Servage, 2005). Moreover, research on e-learning in the workplace cuts across different disciplines including education; computer science; sociology; psychology and management, showing the multidisciplinary nature of the field. In this context, there is a need for a thematic overview of related studies for a comprehensive understanding of this broad and diverse research field. This study adopted a bibliometric approach to analyze 324 relevant articles published in academic journals

and conference proceedings from 2000 to 2012, with the aim of discovering the major research themes and knowledge structure of the field.

2. Related reviews

A number of studies have reviewed the literature on e-learning in the workplace from different perspectives, including theoretical foundations; design principles; evaluation of e-learning programs; and implementation strategies. The earlier reviews on theoretical foundations emphasized the role of cognitive science and in particular, the cognitive information-processing model in the research and development of workplace e-learning environments (DeRouin, Fritzsche, & Salas, 2005b; Salas, Kosarzycki, Burke, Fiore, & Stone 2002). Tynjälä and Häkkinen (2005) reviewed the theoretical bases of e-learning at work from a broad perspective, and outlined the guiding theories from multiple disciplines, including adult learning; learning organization; cognitive sciences; and socio-cultural theories. In the same vein, Ludvigsen and Mørch (2010) claimed that the socio-cultural theory of learning, particularly its dialogical view of learning provides the foundation for a new generation of computer supported collaborative learning environments.

Pedagogical and technological design principles of workplace e-learning are also stressed in most reviews. DeRouin, Fritzsche and Salas (2005a) summarized the research-based guidelines on design for learner control or learning flexibility in workplace e-learning applications. Tynjälä and Häkkinen (2005) reviewed pedagogical challenges and theory-based guidelines for workplace e-learning design and claimed that there was a need to accommodate employees' personal needs and link personal learning to organizational contexts. In other reviews, a variety of design principles were formulated based on relevant learning theories or training design practices (e.g., Salas, DeRouin, & Littrell, 2005; Schreiber, 1998; Lee, 2010; Collis & Margaryan, 2005), most of which originated from either behavioristic or cognitive science models.

Evaluation of e-learning programs in workplace settings is a focus of many studies on workplace e-learning. Issues of effectiveness, return on investment, and completion rates of e-learning programs have been included in relevant reviews. Kirkpatrick's (1976) four-level training evaluation (i.e., learner reactions, learning achievements, work behavior, and organizational results), a widely used evaluation framework, has been discussed in reviews. However, systematic examination of success factors in workplace e-learning is limited in scope, although many empirical studies have explored the effects of individual differences, technological attributes, instructional

design, social influences, and organizational contexts in predicting workplace e-learning success (Park & Wentling, 2007; Roca & Gagne, 2008; Cheng et al., 2011; Harteis, Gruber & Hertramph, 2010; Gunawardena, Linder-VanBerschot, LaPointe, & Rao, 2010; Martin, Massy, & Clarke, 2003).

Other issues taken into consideration in previous reviews include strategizing and implementing e-learning in the workplace settings, that is, *why* and *how* organizations used e-learning, and *what* were the key points of best practices. Regarding the *why* question, prior reviews have shed light on the benefits and drawbacks of e-learning, including cost-effectiveness; delivery-efficiency; self-directed learning; on-demand learning; and flexibility in time and place (Welsh, Wanberg, Brown, & Simmering, 2003; Salas, Kosarzycki, Burke, Fiore, & Stone, 2002). Concerning the *how* problem, reviewers have examined the current state of workplace e-learning practices regarding issues such as learning content development, training technologies, delivery modes, learner engagement, and control and collaboration (DeRouin, Fritzsche, & Salas, 2005b; Servage, 2005). Moreover, best practices; obstacles; solutions; and implementation strategies of workplace e-learning programs are discussed in the reviews (Berge, 2002).

Although these reviews provide an overview of various research issues concerning e-learning in the workplace, they are limited in scope because of their focus on specific aspects. In view of the increasingly complex, dynamic and multidisciplinary nature of the field, this study adopted a meta-perspective on this broad area of research to analyze the domain as a whole in terms of its knowledge structure or research themes.

3. Research design

3.1. Methods of domain analysis

This study adopted a bibliometric analysis approach to examine the literature on e-learning in the workplace. The analysis consisted of two parts: 1) co-word analysis of the keywords indexed in the articles to detect the clusters of research topics; and 2) text analysis of the titles and abstracts of the articles to assist in understanding the research theme of each cluster.

Co-word analysis of keywords

Co-word analysis is an established bibliometric technique widely used in scientometric research to describe and interpret the organization of knowledge in a

scientific discipline (e.g., Lee & Jeong, 2008). It involves a co-occurrence analysis of keywords or meaningful terms in a selected body of literature. Co-occurrence analysis, a central task of association analysis in data mining, is used to identify groups of items highly correlated with each other (Tan, Kumar, & Srivastava, 2004). The purpose of co-word analysis is to map and understand the dynamics of science based on patterns of co-occurrence of pairs of keywords representing the various themes in a discipline (He, 1999). The words occurring in an article are assumed to be associated or related with each other, or to be similar to some extent. Basically, this method involves the use of statistical techniques such as cluster analysis or factor analysis to generate groups of keywords according to the association strength among the terms measured by co-occurrence frequencies obtained from the domain literature. Then graph drawing techniques are used to map out the relationships between the keywords in groups. Based on the position of, and associations between, the keywords in the group, core research topics can be identified (Ding, Chowdhury, & Foo, 2001). To carry out the co-word analysis, four sequential steps are required: 1) keyword extraction and normalization; 2) co-occurrence matrix construction; 3) clustering; and 4) visual presentation of keyword clusters (Lee & Jeong, 2008).

Text analysis of titles and abstracts

Text analysis is the computer-assisted analysis of data contained in a large collection of written texts (Wegerif & Mercer, 1997). It is a corpus-based approach to the empirical exploration of word meaning within contexts (Graddol, Maybin, & Stierer, 1994). The basic steps of text analysis are data selection, corpus building, data cleaning, computer-assisted analysis, and interpretation of results (Popping, 2000). Typical text analysis techniques include word list generation, collocation, and concordance analysis. Word list generation provides word frequency information in texts; collocation is the tendency of words to co-occur; and concordance describes texts in the form of keywords in contexts. A concordance is a listing of principal words used in a corpus, presented with the words immediately surrounding them. As reported in a survey conducted by Romero, & Ventura (2007), corpus-based quantitative text analysis has been applied in empirical educational research (Romero, & Ventura, 2007).

3.2. Sample dataset

The sample data used in this study consisted of 324 published articles in the domain of workplace e-learning. The data were collected through a set of procedures. *First*, Elsevier's Scopus database was selected as the data source. Scopus is one of the world's largest multidisciplinary databases of scientific literature (Bar-Ilan, 2008) and

has been widely used as the data source in studies depicting the dynamics of science and technology (e.g., Gupta & Dhawan, 2009). *Second*, according to the purpose of this study, the search criteria were formulated by including "workplace"; "learning"; "training"; "web"; "online"; and "e-learning" as the entry terms. The following search query was constructed and applied in the database:

(TITLE-ABS-KEY(workplace) AND *(TITLE-ABS-KEY(learning) OR TITLE-ABS-KEY(training))* AND *(TITLE-ABS-KEY(web) OR TITLE-ABS-KEY(online) OR TITLE-ABS-KEY(e-learning)))*

The year range of the sample literature determined as from 2000 to 2012. The source type was limited to English language articles published in journals or conference proceedings. The search produced a total of 601 articles. The researchers of the present study went through the abstract of these articles to remove irrelevant and repeated records. Finally, they selected 324 articles for data analysis. Most of the irrelevant records were those using online surveys to investigate various issues concerning workplace learning but irrelevant to e-learning or technology for learning.

3.3. Data processing

Procedure for co-word analysis of keywords

1) Keyword extraction and normalization. To prepare a keyword library for co-occurrence analysis, the author keywords (provided by authors) and the index keywords (provided by the database system) of all the sample article were extracted. There were 2470 raw keywords and phrases in the sample. The keywords and phrases were then cleaned by aligning words of plural and singular forms, standardizing phrases with and without hyphens, and normalizing uppercase and lowercase words. A total of 2322 keywords or phrases were finally reserved for analysis.

2) Co-occurrence matrix construction. Keywords and phrases appearing three or more times in the sample articles (i.e., 332 keywords and phrases) were selected to build the keywords co-occurrence file. First, a term-document-matrix was built for the 332 keywords from the 324 sample articles, which produced a 332×324 matrix. Then, the term-document-matrix was transformed into a keyword co-occurrence matrix (i.e., a 332×332 matrix). The co-occurrence matrix was then converted into a network file in Pajek (Batagelj & Mrvar, 2009) for further processing. In Pajek, the co-occurrence file was transformed into a dissimilarity matrix based on a dissimilarity measure (Batagelj & Mrvar, 2009).

3) Clustering. Hierarchical clustering using Ward's method was performed on the

dissimilarity matrix to produce a hierarchy of keywords in Pajek. According to the generated hierarchy, a number of clusters of keywords were observed. The cluster level was determined according to Ward's measure of error sum-of-squares within each cluster calculated by Pajek. The identified clusters were then transformed into separate networks in Pajek for graph drawing.

4) Visual presentation of keyword clusters. Each cluster was presented in the form of a graph, in which the keywords were represented by nodes and their associations represented by links between the nodes. Before the graphs were generated, the line values (i.e., dissimilarity) in each network were transformed so that the line width in the graphs indicated similarity (i.e., association) among keywords. To make the graphs readable, the lines with a value lower than the 3rd quartile of the line values in the whole network were set to be invisible in the graphs. Thus, only the strong associations among the keywords (i.e., associations with high values of similarity) were presented as lines in the graphs. To identify the topics in each cluster, the degree centrality of each keyword (i.e., the number of links or relationships owned by the keyword in a network) was calculated and represented by the size of the node. In the graphs, the keywords that had the higher degree centrality (i.e., equal to or higher than the median of the degree centrality of all keywords in the cluster) were highlighted in red, and presented as the central topics of each cluster.

Procedure for text analysis of titles and abstracts

The text analysis of the titles and abstracts of the articles was performed to identify the theme of each cluster. Several steps were taken to implement the text analysis. *Firstly*, from the total sample of 324 articles, those indexed with the keywords with high degree centrality in each cluster were retrieved. *Secondly*, the titles and abstracts of the retrieved articles in each cluster were extracted and built as corpora. *Thirdly*, data cleaning was implemented to remove redundant information from the corpora. Specifically, four types of redundant information were removed from the corpora: a) copyright information contained in the abstracts; b) punctuation (excluding intra-word-dashes); c) numbers; d) stop words including prepositions, articles, and pronouns. *Fourthly*, computer-assisted text analysis was performed on the corpora to generate a word list with frequency and collocates to characterize the texts. The word list presented the high-frequency words appearing in the corpora, while the collocates showed the words (with frequencies) appearing immediately to the left or immediately to the right of a specific word in the word list. Finally, the research theme of each cluster was verified and specified based on the textual information derived from the corpus analysis.

4. Results

4.1. Descriptive characteristics of the articles

Figure 1 presents the number of articles on workplace e-learning published in each year from 2000 to 2012. The bar chart and the interpolation line on the bars show that the number of articles on workplace e-learning continued to increase in general, and that the field was growing and attracting more research interests, especially during 2004-2005 and 2011-2012. There was no article from 2010 in the sample. Appendix 1 lists the sources (i.e., journals and conference proceedings) that published more than one article on workplace e-learning.

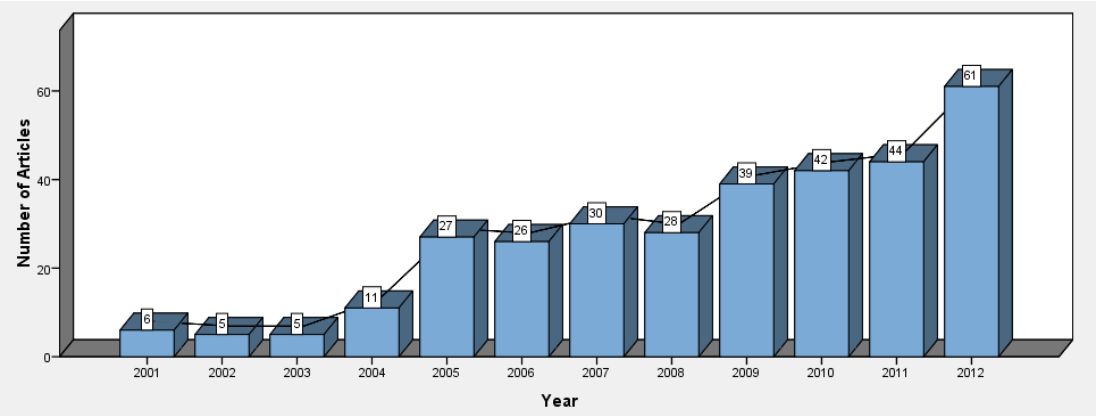

Figure 1. Number of articles on workplace e-learning from 2000 to 2012

4.2. Six clusters

Based on the hierarchical clustering results from the co-word analysis, six clusters of keywords were observed. Figure 2 shows the hierarchy produced via the hierarchical clustering algorithm in Pajek. The six clusters are presented in such a way as to make the within-cluster variance minimal. The sub-trees with "(close)" at the end are the 6 clusters. In each cluster, the keyword with the highest frequency is followed by a "$" and a number as the frequency, and the total number of keywords is indicated in parentheses. The number in the squared bracket in each cluster indicates Ward's measure of error sum-of-squares for that cluster.

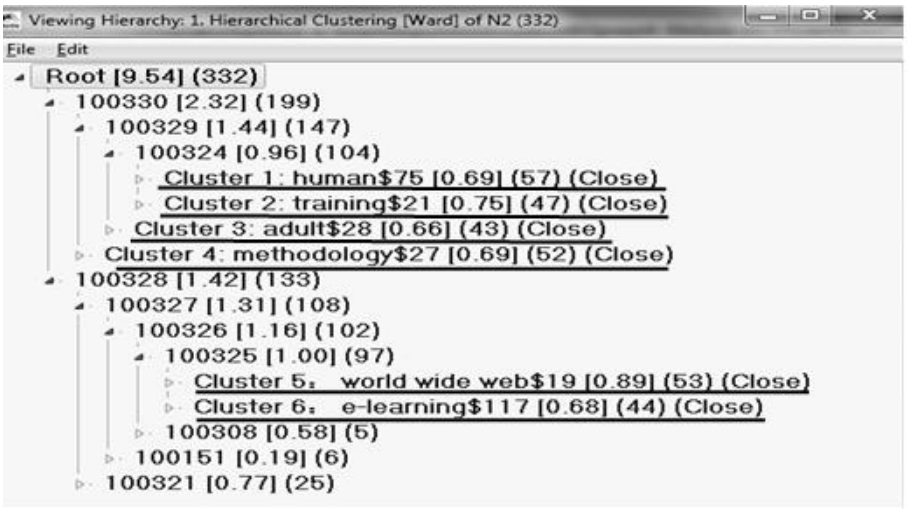

Figure 2. Hierarchy of clusters in Pajek

After the clusters were identified, the keywords of each cluster were drawn from the whole co-occurrence network as separate networks for further analysis. Table 1 presents the keywords with high degree centrality in each cluster, together with their degree of centrality and frequency.

Table 1. Keywords with high degree centrality and frequency in the six clusters

Cluster 1 (N [a] =163, n [b] =57)			**Cluster 2** (N= 101, n=47)			**Cluster 3** (N=56, n=43)		
keywords [c]	*d* [d]	*f* [e]	*keywords*	*d*	*f*	*keywords*	*d*	*f*
human	114	75	training	48	21	female	72	24
internet	94	69	computers	30	12	male	70	21
workplace	90	52	technology	28	19	adult	64	28
medical education	80	28	management	24	9	questionnaire	64	25
curriculum	80	20	problem solving	24	9	controlled study	48	8
teaching	72	43	professional knowledge	24	9	follow up	44	5
education	66	54	professional development	24	8	middle aged	40	14
learning	62	41	productivity	24	5	stress, psychological	36	6
online system	62	19	online learning	22	14	job satisfaction	34	7
review	54	17	decision making	22	6	priority journal	32	18
education program	50	13	long term care	22	3	job stress	30	4
continuing education	50	11	information technology	20	16	In-service training	28	7
clinical practice	44	9	motivation	20	7	web based training	28	6
competence	40	8	information service	20	6	mental health	28	4
evidence based medicine	36	10	professional practice	20	6	Japan	28	3
united kingdom	36	10	evidence-base practice	20	5	stress	24	4
distance education	32	26	feasibility study	20	3	controlled clinical trial	24	3

medical student	32	7	practice guideline	20	3	distress syndrome	24	3
patient care	32	6	salaries and fringe benefits	20	3	health education	24	3
skill	30	8	work	20	3	randomized controlled trial	20	5
nurse	30	6						
computer system	30	4						
educational technology	28	6						
health care personnel	26	7						
education, medical, continuing	26	6						
great Britain	26	6						
medical school	26	5						
physician	26	5						

Cluster 4 (N=55, n=52)			**Cluster 5** (N=72, n=53)			**Cluster 6** (N=184, n=44)		
keywords	*d*	*f*	*keywords*	*d*	*f*	*keywords*	*d*	*f*
nursing education	86	20	world wide web	66	19	e-learning	88	117
attitude of health personnel	82	16	web 2.0	52	16	workplace learning	80	61
health personnel attitude	78	13	user interfaces	44	10	life-long learning	68	14
psychological aspect	78	12	informal learning	36	8	learning system	66	26
computer assisted instruction	76	21	workplace training	30	8	personnel training	64	25
health care quality	76	18	knowledge acquisition	30	7	knowledge management	64	21
education, nursing, continuing	74	13	social network	30	6	multimedia systems	60	14
methodology	72	27	industry	26	11	project management	50	8
attitude to computers	72	10	knowledge	26		societies and institutions	50	7
program evaluation	70	14	social networking (online)	24	7	blended learning	48	14
nursing staff	70	8	knowledge creation	24	4	research	46	10
Canada	64	10	mobile devices	24	4	knowledge workers	46	5
evaluation	62	10	mobile technology	22	4	higher education	42	7
nursing education research	62	8	computer science	20	8	information system	40	18
organization and management	58	13	small and medium sized enterprises (smes)	20	7	individual learning	40	4
professional competence	54	10	social media	20	6	workplace environments	40	4
nursing methodology research	54	5	systems analysis	20	4	academic staff	38	4
human computer interaction	52	10	learning resource	20	3	tacit knowledge	38	3
computer user training	52	8	distance learning	16	10	virtual reality	36	8
clinical competence	44	13	information and communication technologies	16	8	strategic planning	36	3
health knowledge, attitudes, practice	44	8	professional learning	16	6	constructivism	34	6
benchmarking	40	8	knowledge based system	16	5	e-learning environment	34	4
standard	40	8	information science	16	4			
quality control	38	8	social interaction	16	4			
attitude to health	36	5	web services	16	3			
health services needs and demand	36	4						

[a] Number of articles indexed with the keywords with high degree centrality in the cluster; [b] Number of keywords with high degree centrality in the cluster; [c] Keywords with the high degree centrality; [d] Degree centrality of keywords in the network; [e] Frequency of keywords;

The result of the text analysis is shown in Table 2, which lists the ten words with the highest frequency in the title and abstract corpus of each cluster. Table 2 also specifies the indicative word for each cluster (i.e., the words in bold; in cluster 5 two indicative words were identified). An indicative word is a word with a high frequency of occurrence, which has specific meaning in the corpus. In the corpora of all the six clusters, the words "learning", "training", "workplace", and "online" appeared with high frequency. Since these four words were used as the search entries in sample selection, they were expected to have a high level of occurrence. Therefore, these four words were not selected as indicative words.

Table 2. Word list of high-frequency words in the title and abstract corpus in the six clusters

Cluster 1			**Cluster 2**			**Cluster 3**		
Rank	*f*[a]	*Word*	*Rank*	*f*	*Word*	*Rank*	*f*	*Word*
1	547	learning	1	371	learning	1	116	learning
2	208	workplace	2	151	workplace	2	112	training
3	207	based	3	142	training	3	96	based
4	205	training	4	121	based	4	94	were
5	164	their	5	113	theirs	5	80	was
6	146	were	6	111	online	6	74	workplace
7	144	was	7	83	were	7	72	their
8	130	online	8	79	use	8	65	course
9	119	work	9	74	**knowledge**	9	62	**health**
10	118	**education**	10	74	was	10	52	study
Cluster 4			**Cluster 5**			**Cluster 6**		
Rank	*f*	*Word*	*Rank*	*f*	*Word*	*Rank*	*f*	*Word*
1	158	learning	1	287	learning	1	978	learning
2	98	based	2	105	workplace	2	283	workplace
3	80	were	3	74	training	3	195	training
4	79	their	4	73	based	4	180	based
5	75	training	5	68	**knowledge**	5	162	**knowledge**
6	66	was	6	60	**social**	6	158	online
7	65	workplace	7	59	work	7	158	their
8	58	**health**	8	57	online	8	157	work
9	55	course	9	57	paper	9	154	paper

10	53	online	10	56	study	10	149	study	

[a] Frequency of words in the corpus of each cluster

Note: The words in bold are indicative words for each cluster.

The collocates of the indicative words in the title and abstract corpus of each cluster are presented in Table 3, which lists the words appearing either immediately to the right or immediately to the left of the indicative word (e.g. in Cluster 4, "public" can be collocated immediately to the left of "health", as in "public health"; while "professionals" can be collocated immediately to the right of "health", as in "health professionals") as well as the frequency of their appearance. The collocates are used to verify and specify the theme of each cluster.

Table 3. Collocates of the indicative words in the title and abstract corpus of the six clusters

Cluster 1					Cluster 2					Cluster 3				
R [a]	*f* [b]	*f(L)* [c]	*f(R)* [d]	*Collocate* [e]	*R*	*f*	*f(L)*	*f(R)*	*Collocate*	*R*	*f*	*f(L)*	*f(R)*	*Collocate*
1	128	0	0	**education**	1	74	0	0	**knowledge**	1	84	0	0	**health**
2	12	12	0	distance	2	10	4	6	skills	2	8	8	0	public
3	7	7	0	higher	3	10	10	0	professional	3	7	4	3	Learning
4	6	6	0	continuing	4	6	1	5	exchange	4	6	5	1	workplace
5	5	5	0	nursing	5	3	1	2	workplace	5	6	0	6	nurses
6	5	5	0	medical	6	3	1	2	related	6	6	0	6	care
7	5	5	0	engineering	7	3	3	0	learning	7	5	3	2	Safety
8	5	4	1	based	8	3	0	3	building	8	5	5	0	occupational
9	3	3	0	their	9	3	1	2	based	9	5	5	0	mental
10	3	2	1	Technology						10	4	0	4	related
11	3	0	3	programs						11	4	0	4	practitioners
12	3	3	0	patient						12	4	0	4	Informatics
13	3	1	2	online						13	4	0	4	infection
14	3	2	1	learning						14	3	0	3	workers
										15	3	0	3	safety
										16	3	3	0	reproductive
										17	3	0	3	promotion
										18	3	0	3	informatics
										19	3	2	1	based

Cluster 4					Cluster 5					Cluster 6				
R	*f*	*f(L)*	*f(R)*	*Collocate*	*R*	*f*	*f(L)*	*f(R)*	*Collocate*	*R*	*f*	*f(L)*	*f(R)*	*Collocate*
1	64	0	0	**health**	1	60	0	0	**social**	1	168	0	0	**knowledge**
2	17	17	0	public	2	17	0	17	networking	2	18	0	18	management
3	10	0	10	care	3	8	0	8	media	3	12	5	7	sharing
4	6	0	6	nurses	4	7	2	5	learning	4	10	1	9	workers
5	5	5	0	workplace	5	5	0	0	Social	5	8	7	1	learning
6	4	3	1	Safety	6	5	0	5	mobile	6	8	2	6	exchange
7	4	0	4	related	7	4	0	4	networks	7	7	0	7	creation
8	4	3	1	community	8	3	0	3	work	8	7	1	6	based
9	3	0	3	promotion	9	3	1	2	Web	9	6	3	3	skills

10	3	0	3	professionals	10	3	1	2	individual	10	6	0	6	acquisition
11	3	0	3	practitioners	*R*	*f*	*f(L)*	*f(R)*	*Collocate*	11	5	2	3	integration
12	3	3	0	mental	1	68	0	0	**knowledge**	12	4	4	0	their
					2	6	2	4	sharing	13	3	1	2	transfer
					3	5	1	4	skills	14	3	3	0	term
					4	5	5	0	learning	15	3	3	0	practices
					5	5	1	4	building	16	3	0	3	platform
					6	4	0	4	maturing	17	3	3	0	organizational
					7	4	0	4	management	18	3	1	2	network
					8	4	0	4	creation	19	3	0	3	necessary
					9	3	3	0	transfer	20	3	1	2	construction
					10	3	0	3	platform	21	3	1	2	building
					11	3	1	2	network					
					12	3	2	1	exchange					
					13	3	0	3	acquisition					

[a] rank by frequency; [b] frequency; [c] frequency of words at the left first position of the indicative word; [d] frequency of words at the right first position of the indicative word; [e] the frequencies of the indicative words in lowercase and uppercase were merged.

Note: The words in bold are indicative words for each cluster

Figures 3 to 8 present the graphs of the six clusters of keywords, in which the keywords are represented as nodes and their associations as links between the nodes. The naming of each cluster was carried out based on the keywords with high degree centrality (i.e. central topics of a cluster). The naming of each cluster was further verified and specified based on the text analysis results (i.e., the indicative words and their collocates). In addition to central topics, attention was paid to the keywords of emerging importance; that is, those with a lower frequency of occurrence but with a decent degree of centrality. The analysis results of each cluster are elaborated in the following.

Cluster 1: E-learning for continuing education

According to Table 1 and Figure 3, the keywords with high degree centrality in the first cluster are relevant to online or web-based technologies (e.g., internet, online system, distance education), workplace contexts (e.g., workplace, medical education, clinical practice, evidence-based medicine), and issues of continuing education (e.g., curriculum, teaching, learning, education, education program, continuing education). The word list produced from the text analysis of the titles and abstracts shows that the word “education” appeared with a high frequency. Furthermore, the collocation of the indicative word “education” suggests that the central topic of the cluster is concerned with distance education and continuing education applied to medical education and engineering education. Moreover, 69.3% of the sample articles indexed with the keywords with high degree centrality in this cluster appeared in journals relevant to

medical education (e.g., Medical Teacher, Work Based Learning in Primary Care), and others published in journals and conference proceedings in engineering education (e.g., International Journal of Continuing Engineering Education and Lifelong Learning) and general workplace learning (e.g., Journal of Workplace Learning).

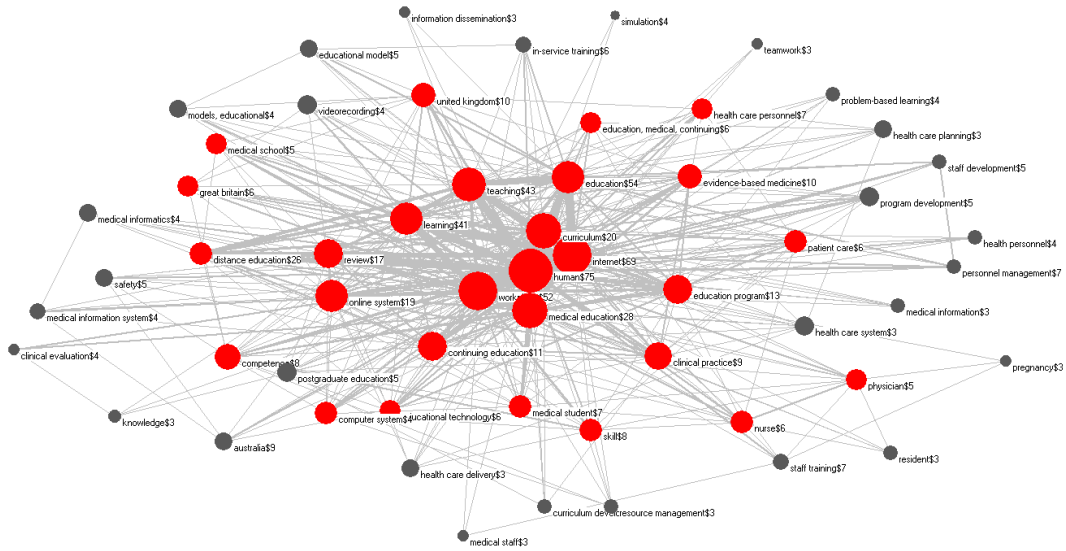

Figure 3. Cluster 1: E-learning for continuing education

In short, the applications of e-learning in continuing education, especially in medicine, were the focus of discussion in the literature pertaining to this cluster. In addition, pedagogical issues (e.g., curriculum, teaching, and learning) and workplace competence attracted more attention in the literature as reflected in the keywords. Given that its focal topics are related not only to medical education but also to engineering education and other types of education, this cluster was defined as e-learning for continuing education.

Cluster 2: Computer-assisted training for professional development

As shown in Table 1 and Figure 4, the keywords with high degree centrality in the second cluster concern training, technologies (e.g., computers, technology, online learning, information technology), and professional practice (e.g., problem solving, professional knowledge, professional development, productivity, decision making). The word list from the text analysis shows that the word “knowledge” appeared to be a high-frequency indicative word in titles and abstracts. The collocates indicate that the cluster is more related to professional knowledge and skills, knowledge exchange, and workplace knowledge. In short, aspects of computer-assisted training for professional development were discussed as focus topics in the literature of this cluster. In addition, the feasibility issue was given much attention in the literature.

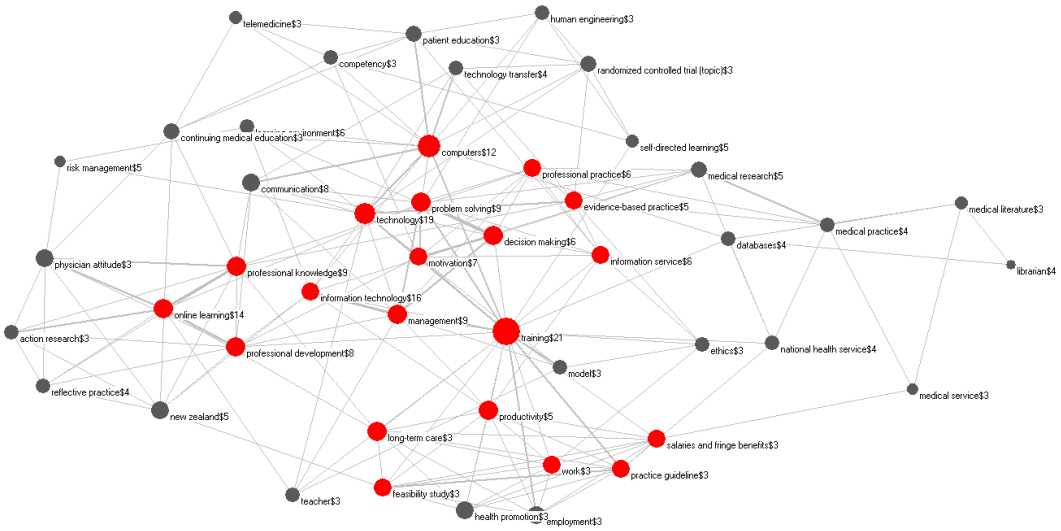

Figure 4. *Cluster 2: Computer-assisted training for professional development*

Cluster 3: Computer-assisted occupational health and safety education

As shown in Table 1 and Figure 5, the keywords with high degree centrality in the third cluster are related to job perception (e.g., job satisfaction, priority journal, job stress,), health issues (e.g., psychological stress, job stress, mental health, stress) and technology for training (e.g., web-based training). The word list generated from the text analysis shows that the word "health" appeared as a high-frequency indicative word in the titles and abstracts. The collocates further indicate that the focus topic in the cluster is about occupational health and safety (e.g., public health, health learning, workplace health, health care, health and safety, mental health). Moreover, 94.6% of the sample articles indexed with the keywords of high degree centrality in this cluster were found in journals related to occupational health, medical education, and health care. In short, aspects of computer-assisted occupational health and safety education were discussed as central topics in the literature of this cluster. It is an area concerned with protecting the health, safety and welfare of people engaged in work or employment. Moreover, questionnaire and controlled study were widely adopted methods in studies on these issues as reflected in the keywords.

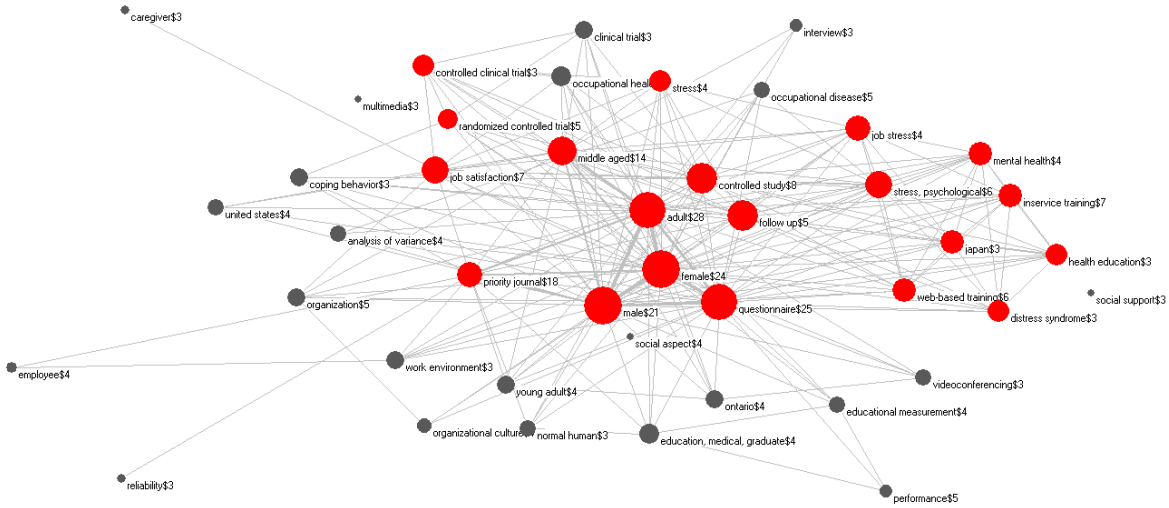

Figure 5. Cluster 3: Computer-assisted occupational health and safety education

Cluster 4: Computer-assisted healthcare and nursing education

According to Table 1 and Figure 6, the keywords with high degree centrality in this cluster are related to workplace contexts in healthcare and nursing (e.g., nursing education, health personnel, healthcare quality, nursing staff) and technology for training (e.g., computer assisted instruction, human computer interaction). The word list from the text analysis also shows that the word "health" appeared frequently in the titles and abstracts. The collocates further indicate that the central topics in the cluster are related to healthcare (e.g., public health, health care, nurses). Moreover, 94.5% of the sample articles indexed with the keywords of high degree centrality in this cluster appeared in journals on nursing education and medical education. In brief, aspects of computer-assisted healthcare and nursing education are focal topics in this cluster. Moreover, keywords relevant to learners' attitude and demand for e-learning received much attention in the literature.

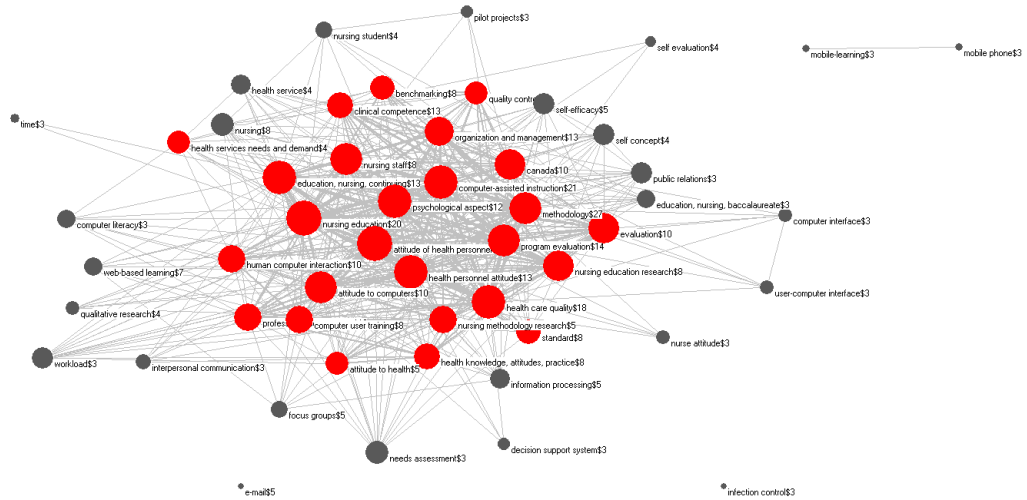

Figure 6. Cluster 4: Computer-assisted healthcare and nursing education

Cluster 5: Social media for informal learning

As shown in Table 1 and Figure 7, the keywords with high degree centrality in the fifth cluster are related to social media technology (e.g., world wide web, web 2.0, social network, social networking, mobile devices, mobile technology, social media), and informal learning in workplaces (e.g., informal learning, workplace training, knowledge acquisition, industry, knowledge creation, small and medium sized enterprises). The word list from the text analysis reveals that the word "social" and "knowledge" appeared as the high-frequency indicative words in the titles and abstracts. The collocates further verify that the central topics in the cluster are related to social media (e.g., social networking, social media, social learning) for informal learning of knowledge and skills (e.g., knowledge sharing, knowledge and skills). In sum, aspects of social media for informal learning were the focus of discussion in this cluster.

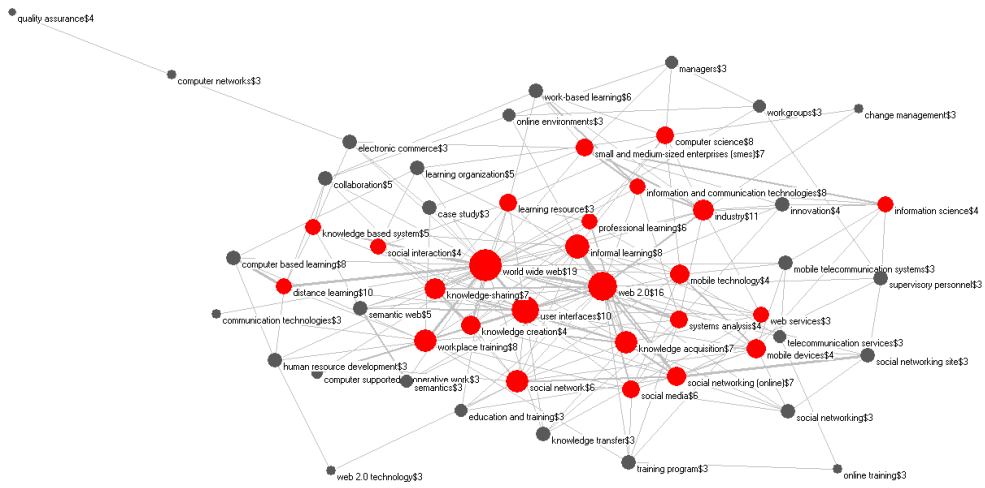

Figure 7. Cluster 5: Social media for informal learning

Cluster 6: Knowledge management in workplace e-learning

According to Table 1 and Figure 8, the keywords with high degree centrality in the sixth cluster are related to technology for learning (e.g., e-learning, learning system, blended learning, information system, multimedia systems), workplace contexts (e.g., workplace learning, lifelong learning, personnel training, workplace environments), and knowledge management (e.g., knowledge management, knowledge workers, tacit knowledge). The word list generated from the text analysis indicates that the word "knowledge" appeared in the titles and abstracts with high frequency. The collocates further indicate that knowledge management, knowledge sharing, knowledge workers, knowledge exchange, and knowledge creation are central topics. In sum, issues of knowledge management emerged as central topics in this cluster. Moreover, the

keywords concerning lifelong learning and tacit knowledge attracted more attention in the literature.

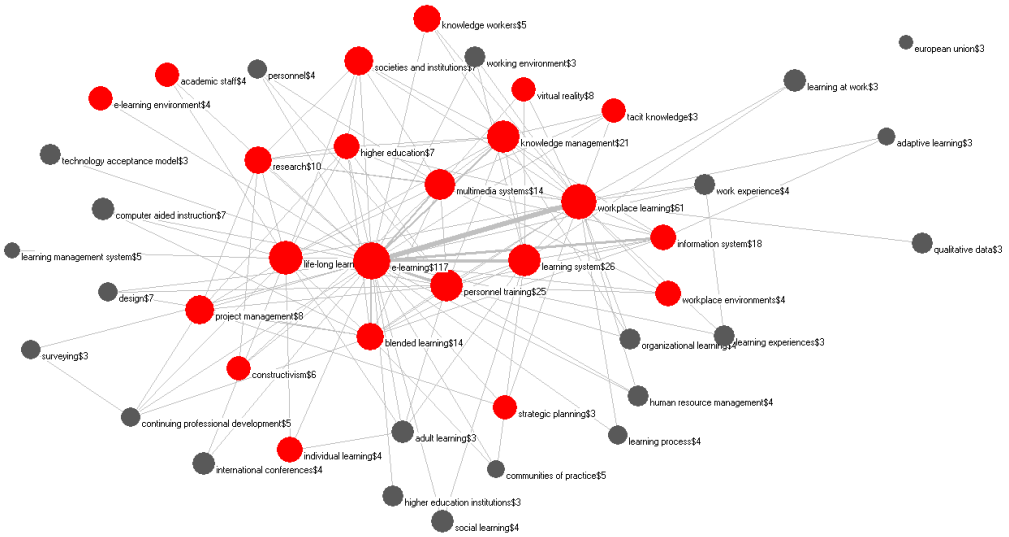

Figure 8. Cluster 6: Knowledge management in workplace e-learning

4.3. Structure of the whole domain

To examine further the internal structure of the clusters, the group density of the each cluster was calculated. Group density (i.e., the average value of the internal links of all the keywords within a group) captures the cohesion of a group (de Nooy, Mrvar, & Batagelj, 2005). Group cohesion exists when group members connect with another. Table 4 presents the group density of each of the six clusters, showing that the fourth and first clusters have the highest density. The result signifies that the research themes defined in the two clusters, i.e., *computer-assisted healthcare and nursing education*, and *e-learning for continuing education*, are the most coherently developed themes in research on workplace e-learning.

Table 4. Group density

Group Density	Cluster
0.697	cluster 4
0.580	cluster 1
0.529	cluster 3
0.428	cluster 6
0.188	cluster 2
0.168	cluster 5

Moreover, according to the clustering hierarchy in Figure 2, there is a closer relation between the first and second clusters, which means that the two themes, *e-learning for*

continuing education and *computer-assisted training for professional development*, are closely related. Both the clusters concern the learning of workplace knowledge and skills, while the former is more related to institutional learning programs associated with vocational and higher education and the latter mainly concerns in-service training or job-oriented professional development.

The clustering hierarchy in Figure 2 also indicates a closer relation between the fifth and sixth clusters, i.e., *social media for informal learning* and *knowledge management in workplace e-learning*. While both clusters are related to the learning of knowledge from work practice or from knowledgeable peers, they have different focuses. Cluster five is mainly about technology-enhanced social interaction to support knowledge exchange or sharing among peers. Cluster six concerns various training or learning programs and technologies to support the capture and transfer of tacit knowledge embedded in practice experience.

5. Discussion

To obtain a thematic overview of studies on workplace e-learning, the research output in the area (i.e., a sample of 324 articles published in journal articles or conference proceedings from 2000 to 2012) was examined to explore the domain literature based on co-word analysis of the keywords and text analysis of the titles and abstracts of the articles. The data analysis results revealed six meaningful research themes in the domain literature.

5.1. Six clusters

The first cluster found in the domain literature was *e-learning for continuing education*. The topics relevant to online or web-based technologies and curriculum-based continuing education or distance education were strongly associated in this cluster and formed a salient research theme. Moreover, topics related to pedagogy and workplace competence were emphasized in the articles. This reflects the current state of studies on vocational and higher education, which require interaction between formal education and practical experience and new pedagogies for technology-enhanced learning (Tynjälä, 2008; Tynjälä & Häkkinen, 2005). The group density of the cluster suggests that it is a coherently-developed area of study. Moreover, it was noted that many articles in this cluster were related to medical education and published in journals in medical education, which, however, has not explicitly been reported in previous reviews of workplace learning research.

The theme of the second cluster was *computer-assisted training for professional*

development. Topics concerning training technologies and professional development of workplace knowledge and skills were found to be strongly associated in this cluster and formulated a salient theme. This finding is in line with Welsh, Wanberg, Brown, & Simmering's (2003) claim that the integration of personnel training with on-demand job support and professional development might become a future direction of workplace e-learning. While covering diversified issues on professional practice and development, this cluster as a whole lacks coherence as reflected by its low density. The keywords analysis shows that the feasibility issue is beginning to receive more attention in the literature.

The third cluster identified in the literature was *computer-assisted occupational health and safety education*. Topics regarding occupational health and technology for training were strongly associated in the cluster and grouped into a well-established field, as reflected in the group density of the cluster. Most of the articles in this cluster appeared in professional journals on occupational health, medical education, and health care. Moreover, research methodology (e.g., questionnaire and controlled study) seemed to receive a great deal of attention in these studies.

The theme of the fourth cluster was *computer-assisted healthcare and nursing education*. Topics concerning healthcare and nursing education and e-learning technologies were strongly associated in the cluster and formed a well-established field. Most articles in this cluster were published in journals related to nursing education and medical education. Moreover, issues of learners' attitude and demand for e-learning were emphasized in the articles. The group density analysis shows that this cluster has the highest density, which means it is a coherently developed study area.

The fifth cluster concerned *social media for informal learning*. This study found that the topics regarding social media technology and informal learning in workplaces were saliently associated and grouped into a cluster. Web 2.0 technologies were reported to provide affordances to informal learning by supporting knowledge exchange based on informal social relations, the development of trust and reputation, and knowledge transfer through mentoring (García-Peñalvo, Colomo-Palacios, & Lytas, 2012; Seufert, 2012; Liu, Macintyre, & Ferguson, 2012). Prior reviews noted that organizations had developed better ways to enhance trainee collaboration and communication through using synchronous and asynchronous communication tools (DeRouin, Fritzsche, & Salas, 2005b). While social media for informal learning involves a variety of issues (such as Web 2.0, informal learning, knowledge

acquisition, and mobile devices), the cluster itself is not coherently developed, as reflected by its low density.

The theme in the sixth cluster was *knowledge management in workplace e-learning*. Different from institutional learning programs, learning in the workplace is built on practical tasks and work situations, with more attention given to tacit knowledge and innovative procedures. Many studies have claimed that the future of e-learning lies in the integration of information and content management, knowledge management, learning management systems, and personnel training (Welsh, Wanberg, Brown, & Simmering, 2003; Rosenberg, 2012; Rossett, 2002). For example, a knowledge visualization approach was proposed to address the problem of "lost-in-hyperspace" in self-directed learning with large amount of online resources (Wang, M., Peng, J., Cheng, B., Zhou, H., & Liu, 2011). Other studies have explored the integration of knowledge management and e-learning (e.g., Wild, Griggs, & Downing, 2002; Marshall et al., 2003; Lytras, Naeve, & Pouloudi, 2005; Schmidt, 2005; Sampson & Zervas, 2013). These issues were found to be strongly associated in the literature and were grouped into a cluster with a moderate level of coherence. Moreover, lifelong learning and tacit knowledge appeared to attract more attention in the literature. While knowledge and learning are directly related, studies on knowledge management place more emphasis on the capture and transfer of tacit knowledge embedded in everyday practice and the commitment to lifelong learning.

5.2. Other related views concerning the domain

The six clusters, derived from the research literature as described above, are largely consistent with several less empirical efforts to specify research areas and emerging technologies pertinent to e-learning in the workplace. For example, the *New Media Consortium (NMC)'s 2014 Horizon Report: Higher Education Preview* (see http://www.nmc.org/pdf/2014-horizon-he-preview.pdf) highlights online, hybrid and collaborative learning as the number one trend likely to have a significant impact on higher education, including formal and informal learning and professional training in the short term. Social media use in learning is cited as the second trend in the NMC report, and this is closely aligned with cluster 5. Another indicator that these clusters are widely recognized is reflected in the European Networks of Excellence on Technology-Enhanced Learning (STELLA; see http://www.stellarnet.eu/) and Game-Based Learning (GALA; see http://www.galanoe.eu/index.php). Both projects recognize the impact of e-learning and other new technologies on learning and instruction in higher education and other domains such as medical training.

Moreover, the findings of this study are consistent with a recent review of the literature on workplace learning (Tynjälä, 2013), although technology is not included in its scope. Among the lines of research identified in Tynjälä's (2013) review, learning in education-work contexts in vocational and higher education aligned with cluster 1, professional expertise development aligned with cluster 2, and research on communities of practice and organizational learning aligned with clusters 5 and 6. Learning through communities of practice is highly related to informal learning through sharing and social networking (Lave & Wenger, 1991). Organizational learning is closely allied with knowledge management in that individuals in an organization collectively acquire, share and manage knowledge to enable the organization continuously and effectively to learn and adapt to the environment (Argyris, 1999; Nonaka & Takeuchi, 1995; Wang & Yang, 2009). At the same time, communities of practice, knowledge management, and organizational learning practices have been considerably promoted by technology in recent decades.

5.3. Holistic view of the state of art with future work

While each of the six themes highlight certain important aspects of research on workplace e-learning, the themes complement each other and make it possible to form a holistic picture of this complex domain. Based on the six themes, the research on workplace e-learning was categorized into four dimensions: e-learning for continuing education and professional development, e-learning in the healthcare sector (as one of the most prolific e-learning initiatives), use of social media for e-learning, and integration of knowledge management with e-learning.

The first dimension: e-learning for continuing education and professional development, represents the mainstream of research on workplace e-learning. Formal learning programs in vocational and higher educational institutions as well as in-service training or professional development programs in workplaces constitute the most significant part of workplace learning (Tynjälä, 2008). Both of them have been considerably altered and supported by e-learning or distance learning technologies. At the same time, formal learning and informal learning have been increasingly integrated with the support of technology, providing more expansive and flexible approaches to workplace learning and lifelong learning. Institutions and organizations that embrace face-to-face/online hybrid learning models and support the integration of technology, pedagogy and content have the potential to take advantage of the best of the new learning models (Rosenberg, 2012; Wang, Jia, Sugumaran, Ran, & Liao, 2011).

The second dimension: e-learning in the healthcare sector, has emerged as one of the most prolific e-learning initiatives. The world of healthcare is being transformed through e-health innovations including widespread implementation of healthcare information systems, electronic health records, medical decision support systems, Web-based conferencing, imaging technologies, among others. In addition to their impact on healthcare services, the e-health innovations have pushed the integration of technology into training of medical, nursing, physiotherapy, social work and other allied health professionals (Kushiniruk, 2011). Information and communication technologies and their applications in heath services have made flexible and timely delivery of learning for the health workforce imperative (Booth, Carroll, Papaioannou, Sutton & Wong, 2009; Childs, Blenkinsopp, Hall, & Walton, 2005). It is surprising that three distinctive clusters (cluster 1, 3 and 4) identified in this study are relevant to health or medical education, which suggests that applications of e-learning in the healthcare sector have become a major focus of interest in the field of workplace e-learning. However, these studies were almost non-existent in previous reviews on workplace e-learning, probably because most of them were published in medical or healthcare related journals.

Studies on workplace e-learning in the above two dimensions have paid particular attention to pedagogy and e-learning success factors. It is critical to bridge the gaps between formal and informal learning and between education and work, especially in the development of new pedagogical models such as blended learning, problem-based learning, computer-assisted collaborative learning, and simulation-based authentic learning. For example, while learning through problem solving has been widely recognized as an effective means of learning especially in complex domain such as medical education, knowledge embedded in problem-solving practice may remain inert and not transferrable to new problems; it is crucial to utilize relevant learning technology to visualize and facilitate the connection between problem solving and knowledge construction (Wang, Wu, Kinshuk, Chen, & Spector, 2013). In examining the success factors of workplace e-learning, studies have taken into account a variety of issues, such as learners' motivation and attitudes; associated costs; technical and administrative support; and cultural shift strategies. However, there is a need for more systemic research on assessing the outcomes of workplace e-learning. More ambitious learning outcomes such as problem-solving competence, human development, and organizational change need to be examined in future studies. More importantly, learning outcomes should be appropriately assessed in consistence with learning objectives, which involve both individual needs and organizational goals as well as the alignment of the two (Wang, 2011).

The third dimension: social media is playing an increasingly important role in workplace e-learning. The new landscape driven by social medial and its culture of networking, sharing, and collaboration is fundamentally altering people's relationships and activities with information and knowledge. The use of social media and networking tools have significantly improved knowledge creation and sharing in the workplace by engaging and empowering people in social interaction (McAfee, 2009; García-Peñalvo et al., 2012). However, many studies on social media are limited to the superficial use and analysis of the tools without taking into account the organizational contexts that may affect the essential attributes of social and collaborative behavior, such as trust, voluntariness, and self-directness. These issues need to be explored in future studies on the use of social media for learning. On the other hand, more effort is needed to investigate different types of communities of practice (e.g. interaction between expert and novice and interaction between people with different skills or expertise [Fischer, 2013]) and their impact on learning in the workplace.

The fourth dimension: integration of knowledge management with e-learning has been constantly promoted in organizational environment. Knowledge management is a discipline aimed at enabling individuals in an organization or community to acquire, share and manage knowledge collectively to achieve common goals (Nonaka & Takeuchi, 1995). Reiser and Dempsey (2012) identified knowledge management as one of the ten trends affecting the field of instructional design and technology. Different from traditional education, learning in workplace contexts requires employees to capture intuition or tacit knowledge, contribute to the creation of new knowledge, and manage knowledge assets for continuous improvement. Moreover, learning and knowledge management share a common strategy of creating a learning organization, which implies that learning in the organizational context should go beyond the individual level, and an organization should be able to learn and adapt to the environment (Wang & Yang, 2009). However, research on organizational learning is currently not well established and has a weak influence in the workplace e-learning field. Substantial research is needed on how organizational systems, structures, and policies can be incorporated into workplace e-learning applications in order to create a coherent and manageable system for both individual and organizational learning.

6. Conclusion

E-learning, by virtue of its anticipated benefits of just-in-time delivery and cost efficiency, has increasingly been adopted in workplace settings and has resulted in the

large number of studies on e-learning in the workplace. With the aim of exploring the intellectual structure developed in the broad field of workplace e-learning research, this study performed a domain analysis using co-word analysis and text analysis approaches to examine the literature. The literature analysis based on the sample articles revealed six meaningful research themes in the domain: 1) *e-learning for continuing education*; 2) *computer-assisted training for professional development*; 3) *computer-assisted occupational health and safety education*; 4) *computer-assisted healthcare and nursing education*; 5) *social media for informal learning*; and 6) *knowledge management in workplace e-learning*.

All six clusters have distinctive features in characterizing the current research endeavor in the field of workplace e-learning, and they complement each other to form a holistic picture of this complex domain. These research clusters should not be seen as strict, exclusive categories; rather, they should be seen as analytic tools that help make sense of the rich diversity in this research field and help researchers to locate their main areas of interest in this broad field.

Based on the six clusters, the research on workplace e-learning is further categorized into four dimensions: e-learning for continuing education and professional development, e-learning in the healthcare sector (as one of the most prolific e-learning initiatives), use of social media for learning, and the integration of knowledge management with e-learning. Directions for future work under each dimension are also discussed.

It is important to note the potential synergy among these clusters or dimensions. To achieve maximum impact in any cluster area, it is likely that another cluster will have a role to play. For example, social media for informal learning can play a significant role in healthcare education, especially with those working in isolation from local mentors and experts. The role of knowledge management can influence the other clusters in significant ways, especially as the means for creating new knowledge and disseminating it in meaningful and relevant ways.

The limitations of the study should be noted. *Firstly*, although bibliometric analysis is considered a well-established method for analyzing the intellectual structure of, and identifying the patterns or trends of, the domain, there are still some disadvantages with this method. For example, predefined keywords are more limiting than freely chosen keywords as they vary from person to person; inconsistencies may exist between the keywords selected by the authors of the article and the content of the

article. *Secondly*, the literature analysis was based on a sample of articles collected from the Elsevier Scopus database. While Scopus is one of the world's largest multidisciplinary databases of scientific literature and is widely used as the data source in studies depicting dynamics of science and technology, there is a possibility that some literature in the domain might not be included in the database. *Thirdly*, this study focused primarily on English-based journals and conference proceedings. Since workplace e-learning is a global issue, it would be interesting to see future studies that include publications in other languages and investigations in other contexts as well.

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Appendix 1. Journals with the high number articles

Source title	f[#]
Journals	
Journal of Workplace Learning	20
T and D	13
Development and Learning in Organizations	7
International Review of Research in Open and Distance Learning	7
British Journal of Educational Technology	4
Behavior and Information Technology	3
BMC Medical Education	3
Distance Education	3
Educational Technology and Society	3
Human Resource Management International Digest	3
International Journal of Training and Development	3
Journal of E-Learning and Knowledge Society	3
Medical Teacher	3
Work Based Learning in Primary Care	3
Australasian Journal of Educational Technology	2
Clinical Teacher	2
Computers and Education	2
Computers in Human Behavior	2
Education and Training	2
Innovations in Education and Teaching International	2
Interactive Learning Environments	2
International Journal of Continuing Engineering Education and Lifelong Learning	2
International Journal of Learning	2
Journal of Advanced Nursing	2
Journal of Allied Health	2
Journal of Asynchronous Learning Network	2
Journal of European Industrial Training	2
Journal of Interactive Learning Research	2
Journal of Medical Systems	2
Journal of Nursing Management	2
Journal of Occupational Health	2
Journal of Workplace Behavioral Health	2
Knowledge Management and E-Learning	2
Library Management	2
Nurse Education in Practice	2

Nurse Education Today	2
Nursing leadership (Toronto, Ont.)	2
TechTrends	2
Turkish Online Journal of Distance Education	2
VINE	2
Welding Design and Fabrication	2
Conference proceedings	
ASCILITE 2011 - The Australasian Society for Computers in Learning in Tertiary Education	14
Frontiers in Education Conference	7
IADIS International Conference e-Learning 2011	6
ASEE Annual Conference and Exposition	5
ACM International Conference Proceeding Series	3
WEBIST 2008 - 4th International Conference on Web Information Systems and Technologies	3
15th Americas Conference on Information Systems 2009, AMCIS 2009	2
ASEE Annual Conference Proceedings	2
Conference on Human Factors in Computing Systems	2
CSEDU 2012 - Proceedings of the 4th International Conference on Computer Supported Education	2
The 8th IEEE International Conference on Advanced Learning Technologies, ICALT 2008	2

[#] Number of articles in journals